

***What aviation functions require automation (**pilot aids**)
and/or autonomy (**with decision authority**)
to achieve UAM (**AAM**) Maturity Levels 2 and 4?***

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The Vehicle: Piloted & Unpiloted (UAS) Paths to AAM

Retrofit (UML-1,2)



Early operations in complex environments with a traditional crew/pilot for safety, acceptance.

SVO (UML-3)



Experience allows transition to single-pilot operations and later, redefined pilot training.

Safety Pilot (UML-4)



Operations with ground-based PIC and onboard safety pilot. Safety pilot removed in late stages.

UAS Operations



Development of vehicle autonomy, datalink, certification process.

AAM Trials (UML-1,2,3)



Operations in sparsely populated areas with no humans onboard. Maturation of resilient autonomy, ATC/UTM, datalink.

AAM Certification (UML-4)



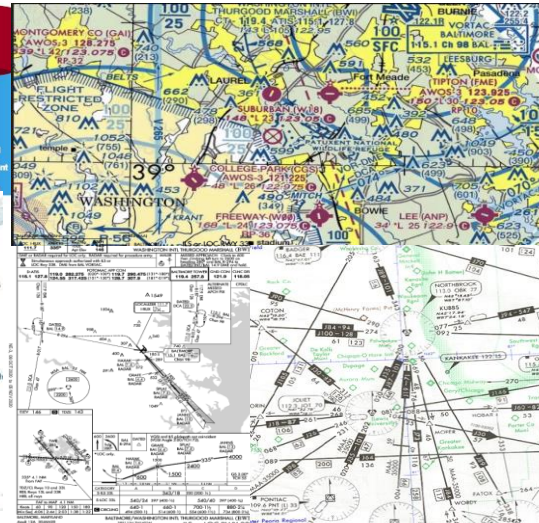
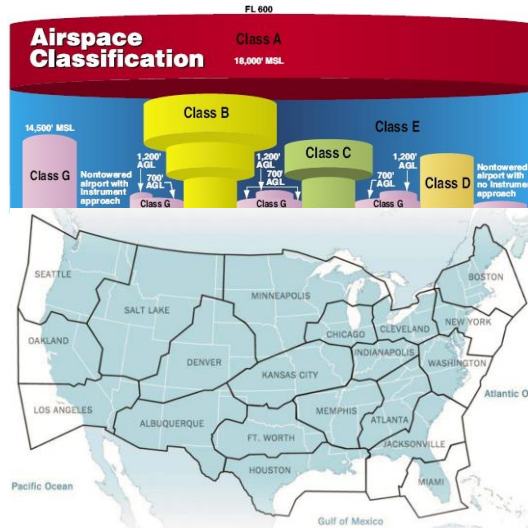
Cargo operations in realistic UAM / AAM conditions with ground-based supervision. Logistics, trust, acceptance, certification milestones.

Integrated AAM (UML-5,6)



Deployed UAM/AAM Cargo & Passenger Operations. Supervisor maintains operational control of many aircraft. Operational control means the exercise of authority over initiating, repurposing, or terminating flight(s).

The Airspace: ATC & UTM Paths to AAM



Legacy ATC/ATM (UML-1,2,3): Piloted Path



Hobby/UAS Flight (UML-1): Unpiloted/UAS Path



Low-Altitude UTM (UML-2,3,4)

ATC for AAM (UML-4,5,6)



- Ubiquitous Datalink
- Map, Airspace, Procedure Data
- Dynamic Flight Routing / Rerouting
- Airspace Reservation & Deconfliction
- Real-time Traffic, WX, & Flight Plan Data
- Contingency Management
- Worldwide Compatibility
- Legacy/voice support???

AAM/UAM Automation Functions^{1,2}

Perceive

Sensor fusion and state estimation

Analyze and Decide

Inner-loop control, flight planning, etc.

Warn/Inform

Keep human in the loop, recognize failure events

Act

Maintain flight control & trajectory

Limit

Prevent and override unsafe inputs/conditions

Integrate

Coordination between automation components

- Four levels of automation: No capability, Limited, Nominal, Comprehensive

[1] Stouffer, V. L., & Goodrich, K. H. (2015). State of the Art of Autonomous Platforms and Human-Machine Systems: Only a Fool Would Stand In the Way of Progress. *15th AIAA Aviation Technology, Integration, and Operations Conference*, (June), 1–15. <https://doi.org/10.2514/6.2015-3036>

[2] Mathur, A., Panesar, K., Atkins, E.M., Sarter, N. (2019). Paths to Autonomous Vehicle Operations for Urban Air Mobility. In *AIAA Aviation 2019 Forum*. <https://arc.aiaa.org/doi/10.2514/6.2019-3255>

Automation for UAM Maturity Levels (UML) 2,4

- *The UML's are phrased to follow the "Piloted Aircraft" path, yet leveraging UAS path technologies is critical to efficient vehicle maturation and airspace integration...*
- UML-2: Low Density & Complexity Commercial Operations with Assistive Automation
 - Dual voice/datalink services for enhanced situational awareness
 - Rerouting advisories/automation for local separation assurance & collision avoidance (aircraft & terrain)
 - Health monitoring and management with improved pilot & company dispatch interfaces
 - Comprehensive flight data recording to support machine learning product development & certification
- UML-4: SVO: Medium Density & Complexity Operations with Collaborative & Responsible Automated Systems
 - Automation for dynamic aircraft routing and airspace allocation negotiation
 - Autonomous "co-pilot" with checklist, flight plan execution, communication, rerouting authority
 - Collaborative contingency management with auto-land function